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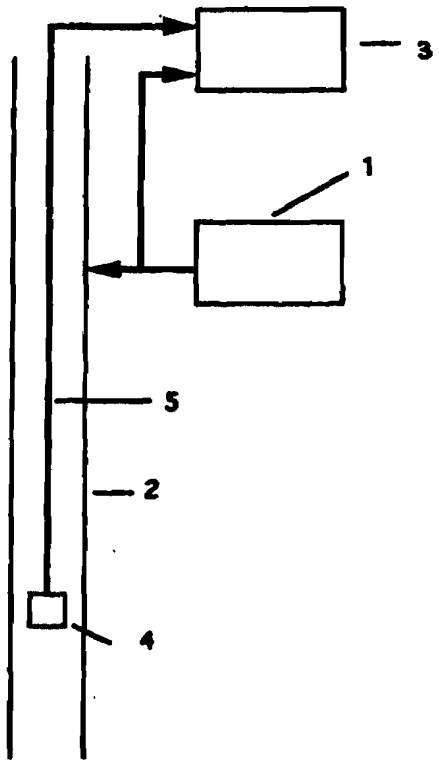
(54) Title: APPARATUS FOR SENSOR LOCATION

(57) Abstract

Apparatus for determining the location of a sensor (4) within channel means (2), which apparatus comprises signal means (1) by which an appropriate signal can be applied to the channel means (2), and processing means (3) for measuring the time difference between a signal from the signal means (1) and a measured signal from the sensor (4).



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APPARATUS FOR SENSOR LOCATION

The invention relates to apparatus for determining the location of sensors within channels. The invention is especially relevant in the oil industry for determining the location of sensors which have been pumped into oil and gas wells.

As oil and gas reserves have been consumed over the years, the extraction of the oil and gas has become increasingly difficult under more demanding conditions. Accordingly, there is a need for the reserves to be more widely monitored to a higher quality than hitherto, and this is particularly so for oil and gas reserves which lie beneath the sea bed. Optical fibre sensors, together with optical fibre cables to link the sensor to the measurement instrumentation, are being developed for this purpose since they offer specific advantages, particularly in the ability to withstand extremes of high pressure and temperature. Furthermore, such optical fibre sensors may be of a structure and diameter similar to those of the optical fibre cable itself. Sensors are being developed which can be remotely deployed into oil wells through conveniently sized hydraulic tubing.

At present, the only known methods for determining the location of a sensor within a channel such, for example, as hydraulic tubing is either to measure the length of fibre cable which has been deployed into the channel or to employ a docking mechanism which enables the sensor to be locked in position when it reaches its desired location. The former method is not believed to be sufficiently accurate, and the latter method places certain restrictions on sensor design.

An aim of the present invention is to allow a wide variety of sensors to be located accurately in channels.

Accordingly the present invention provides apparatus for determining the location of a sensor within channel means, which apparatus comprises signal means by which an appropriate signal can be applied to the channel means, and processing means for measuring the time difference between a signal from the signal means and a measured signal from the sensor.

The apparatus may include sensor communication means for communicating the signal from the sensor to the signal processing means.

The signal means may be a piezoelectric element which produces the signal in the form of an acoustic signal.

The channel means may be narrow bore hydraulic tubing filled with fluid. The fluid may be a liquid or a gas.

The apparatus may include the sensor. The sensor may be an optical fibre sensor.

The sensor communication means may include an optical fibre cable, sensor readout electronics, and an electric cable.

The processing means may be an oscilloscope for displaying both the signal from the signal means and the measured signal from the sensor. The location of the sensor down the channel means may be determined from the time delay which can be measured from the oscilloscope.

In a first embodiment of the present invention, the apparatus includes second channel means, and is one in which the signal from the signal means is applied to the second channel means. Energy from the signal propagated down the second channel means is coupled to the first channel means by signal coupling means. Signals from the sensor and a signal detection means are

processed by the processing means in order to determine the location of the sensor relative to the second channel means.

In the first embodiment of the invention, the first channel means may be hydraulic conduit attached, for example strapped, to the outside of the second channel means.

The second channel means may be production tubing through which oil and/or gas flows up to the surface from an oil or gas reservoir.

The signal applied to the second channel means may be an acoustic signal generated by a piezoelectric element, of such a frequency that it may be transmitted through the second channel means without suffering undue attenuation.

The apparatus may include signal coupling means, for example straps, which are used to fix the first channel means, for example hydraulic tubing, to the outside of the second channel means.

The apparatus may include signal detection means in the form of an acoustic sensor attached, for example strapped, to a known location on the side of the second channel means.

The sensor may be a single acoustic sensor, a number of independent acoustic sensors, or an array of linked acoustic sensors.

The processing means may include digital signal processing means in order to average the signals received from the apparatus and thereby improve the accuracy of the sensor location. Where there is more than one sensor, then the processing means may include means for locating each sensor based upon the timing information between the detected signal from the respective sensor and the signal detection means.

In a second embodiment of the present invention, the apparatus includes second channel means, and is one in which the sensor is a distributed temperature sensor, which is able to measure temperature at many points along the first channel means. The apparatus may include valve means, and may be one in which signal means provides a control signal to open the valve means which allows material, such as oil or gas having a different temperature, to flow up the second channel means. The apparatus may include one or more thermal path means between the second channel means and the first channel means in order to communicate the temperature to the first channel means.

In the second embodiment of the invention, the first channel means may be hydraulic tubing which is thermally lagged between the discrete thermal path means in order to provide a signature in the measured response from the distributed temperature sensor corresponding to the locations of the thermal path means.

The second channel means may be production tubing in an oil or gas reservoir.

The thermal path means may be straps used to strap the second channel means to the first channel means.

The location of the distributed temperature sensor with respect to the second channel means may be determined by inspecting the measured temperature profile where the locations of the thermal strap means will be clearly visible.

In a third embodiment of the present invention the apparatus includes reflection means, for example positioned at the end of the channel means. The signal applied by the signal means to the channel means can be measured by the signal detection means and then measured again after reflection. The processing means can thus reference the location of the sensor by centering the signal

received from the sensor within the window of the first and second signals received from the signal detection means.

In the third embodiment of the invention, the channel means may be hydraulic conduit filled with hydraulic oil and attached, for example strapped, to the outside of production tubing in an oil well.

The reflection means may be a termination at the end of the channel means, or may be the transition between two sections of tubing having different diameters.

The signal means may be a pump which is able to provide a step input of pressure to the channel means.

The signal detection means may be a pressure sensor which measures the pressure within the channel means.

The sensor may be an optical fibre pressure sensor which has been pumped down the hydraulic conduit. It will be appreciated that this technique can be used to determine the position of such a pressure sensor as it is pumped along a hydraulic conduit. Such an application could be improved by the provision of a number of partial reflection means at intervals along the hydraulic conduit. It will also be appreciated that a sensor having an acoustic response would detect any noise reflected by the partial reflection means as the sensor passes along the channel. This noise may be enhanced deliberately by devices fixed to the channel which strike the side of the channel, or interrupt the fluid flow, thereby making a distinctive noise.

It will also be appreciated that reflection means may also be added to second channel means, to which the first channel means may be attached. Signals transmitted down the second channel means and reflected from the reflection means would be detected in the channel means. The second channel means may be production tubing in an oil or gas well.

In a fourth embodiment of the present invention, the apparatus includes first signal detection means which is located at one end of the channel means, and second signal detection means which is located at the other end of the channel means. The signal means applies a time-varying signal to the channel means, and the location of the sensor is determined in the processing means by measuring the phase shift between signals measured by the first and second signal detection means and the sensor.

In the fourth embodiment of the invention, the signal means may be a pump applying pressure which varies sinusoidally to the channel means.

The first and second signal detection means may be pressure gauges.

The sensor may be a pressure sensor.

The signal processing means may be a vector voltmeter.

It will be appreciated that ambiguities in sensor location may be resolved by applying different frequencies measuring the phase shift between the sensor and the first and second signal detection means at different signal frequencies.

Embodiments of the invention will now be described solely by way of example and with reference to the accompanying drawings in which:

Figure 1 is a diagram of an embodiment of the present invention in which a signal is applied to channel means;

Figure 2 is a diagram of an embodiment of the present invention where the signal is applied to second channel means in an oil well;

Figure 3 is a diagram of an embodiment of the present invention allowing the location of a distributed temperature sensor;

Figure 4 is a diagram of an embodiment of the present invention in which a signal is reflected back towards signal means from reflection means at the end of channel means; and

Figure 5 is a diagram of an embodiment of the present invention where a signal detection means is placed at both ends of the channel means.

With reference to Figure 1, signal means 1 is employed to propagate an appropriate signal along channel means 2, the signal also being an output to processing means 3. A sensor 4 is situated within the channel means 2 and the detected signal from the sensor 4 is communicated back to the processing means 3 by means of an appropriate sensor communication means 5.

The apparatus shown in Figure 1 may be used to determine the location of a sensor 4 such as an optical fibre pressure sensor which has been pumped along the channel means 2. The channel means 2 may in this example be a length of hydraulic control line of 1/4" (6 mm) diameter attached to the outside of the production string of an oil or gas well through which oil or gas flows from the reservoir to the surface. The sensor communication means 5 may comprise a length of optical fibre cable which connects the optical fibre pressure sensor to its instrumentation. The hydraulic steel control line is filled with a first fluid such as water. The signal propagated along the hydraulic steel control line comprises flowing a second fluid such as dry nitrogen at a measured pressure and flow rate through the hydraulic steel control line. The processing means 3 may use the time difference from the application of the second fluid to a measured discontinuity in the output of the pressure sensor within the hydraulic steel control line in order to locate the position of the pressure sensor. The applied pressure may be approximately constant in order to simplify the detection of the measured discontinuity in the output of the pressure sensor. It would be convenient to measure the volume of fluid expelled from the hydraulic steel control line in order to calibrate the measurement. The calibration would need to take into account changes in the density of fluids with temperature and pressure. The temperature distribution may be measured by pumping a suitable

optical fibre along the hydraulic steel control line and using a distributed temperature profiling instrumentation (such as a York DTS 80) to output the temperature profile.

With reference to Figure 2, signal means 1 is employed to propagate an appropriate signal along second channel means 21 to which first channel means 24 is attached. Energy from the signal propagating down the second channel means 21 is coupled to the first channel means 24 by signal coupling means 23, and measured by signal detection means 22. Signals from the sensor 4 and the signal detection means 22 are passed to the processing means 3 in order to determine the location of the sensor 4 relative to the second channel means 21.

With reference to Figure 3, the sensor 4 is a distributed temperature sensor 31 allowing the temperature profile along the first channel means 24 to be measured. The signal means 1 provides a control signal to open valve means 32 which allows a fluid such as oil or gas having a different temperature to flow up the second channel means 21. There is provided one or more thermal path means 33 between the second channel means 21 and the first channel means 24 in order to communicate the temperature change to the first channel means 24. The locations of the thermal path means 33 will be visible on the measured response from the distributed temperature sensor 31. Location is provided by reference to the known hardware design of the oil or gas well.

With reference to Figure 4, there is provided a reflection means 41 at the end of the channel means 2. The signal applied by the signal means 1 to the channel means 2 can be measured by the signal detection means 22 and then measured again when it is reflected back. The processing means 3 can thus reference the location of the sensor 4 by centering the signal received from the sensor 4 within the window of the signals received from the signal detection means 22.

With reference to Figure 5, first signal detection means 51 is located at one end of the channel means 2, and second signal detection means 52 is located at the other end of the channel means 2. The signal means 1 applies a time-varying signal to the channel means 2, and the location of the sensor is determined in the processing means 3 by measuring the phase shift between signals measured by first and second signal detection means 51,52 and the sensor 4.

It is to be appreciated that the embodiments of the invention described above with reference to the accompanying drawings have been given by way of example only and that modifications and additional components may be provided to enhance the performance of the apparatus.

CLAIMS

1. Apparatus for determining the location of a sensor within channel means, which apparatus comprises signal means by which an appropriate signal can be applied to the channel means, and processing means for measuring the time difference between a signal from the signal means and a measured signal from the sensor.

2. Apparatus according to claim 1 and including sensor communication means for communicating the signal from the sensor to the processing means.

3. Apparatus according to claim 1 or claim 2 in which the signal means is a piezoelectric element which produces the signal in the form of an acoustic signal.

4. Apparatus according to any one of the preceding claims in which the channel means is narrow bore hydraulic tubing filled with fluid.

5. Apparatus according to any one of the preceding claims and including the sensor.

6. Apparatus according to claim 2 in which the sensor communication means includes an optical fibre cable, sensor readout electronics, and an electric cable.

7. Apparatus according to any one of the preceding claims in which the processing means is an oscilloscope for displaying both the signal from the signal means and the measured signal from the sensor.

8. Apparatus according to any one of claims 1 - 7 and including second channel means, and in which the signal for the signal means is applied to the second channel means.

9. Apparatus according to claim 8 in which the first channel means is a hydraulic conduit attached to the outside of the second channel means.

10. Apparatus according to claim 8 or claim 9 in which the second channel means is production tubing which oil and/or gas flows up to the surface from an oil or gas reservoir.

11. Apparatus according to claim 9 or claim 10 and including signal coupling means which is used to fix the first channel means to the outside of the second channel means.

12. Apparatus according to claim 11 in which the signal coupling means are straps, and in which the first channel means is hydraulic tubing.

13. Apparatus according to any one of claims 8 - 12 and including signal detection means in the form of an acoustic sensor which is attached to a known location on the side of the second channel means.

14. Apparatus according to any one of claims 8 - 13 in which the sensor is a single acoustic sensor, a number of independent acoustic sensors, or an array of linked acoustic sensors.

15. Apparatus according to any one of claims 8 - 14 in which the processing means includes digital signal processing means in order to average many signals received from the apparatus in order to improve the accuracy of the sensor location.

16. Apparatus according to claim 15 in which there is more than one sensor, and in which the processing means includes means for locating each sensor based on timing information between the detected signal from the respective sensor and the signal detection means.

17. Apparatus according to any one of claims 1 - 7 and including second channel means, and in which the sensor is a distributed temperature sensor which is able to measure temperature at many points along the first channel means.

18. Apparatus according to claim 17 and including valve means, and in which the signal means provides a control signal to open the valve means which allows material such as oil or gas having a different temperature to flow up the second channel means.

19. Apparatus according to claim 18 and including one or more thermal path means between the second channel means and the first channel means in order to communicate the temperature to the first channel means.

20. Apparatus according to claim 19 in which the first channel means is hydraulic tubing which is

thermally lagged between the discrete thermal path means in order to provide a signature in the measured response from the distributed temperature sensor corresponding to the locations of the thermal path means.

21. Apparatus according to any one of claims 17 - 20 in which the second channel means is production tubing in an oil or gas reservoir.

22. Apparatus according to claims 19 or 20 in which the thermal path means are straps to strap the second channel means to the first channel means.

23. Apparatus according to any one of claims 1 to 7 and including reflection means.

24. Apparatus according to claim 23 in which the channel means is hydraulic tubing filled with hydraulic oil and attached to the outside of production tubing in an oil well.

25. Apparatus according to claim 23 or claim 24 in which the reflection means is a termination at the end of the channel means.

26. Apparatus according to claim 23 or claim 24 in which the reflection means is the transition between two sections of tubing having different diameters.

27. Apparatus according to any one of claims 23 to 26 in which the signal means is a pump which is able to provide a step input of pressure to the channel means.

28. Apparatus according to any one of claims 23 - 27 in which the signal detection means is a pressure sensor which measures the pressure within the channel means.

29. Apparatus according to any one of claims 23 to 28 in which the sensor is an optical fibre pressure sensor which has been pumped down the hydraulic conduit.

30. Apparatus according to any one of claims 24 to 29 and including reflection means which is added to second channel means.

31. Apparatus according to claim 30 in which the second channel means is production tubing in an oil or gas well.

32. Apparatus according to any one of claims 1 - 7 and including first signal detection means which is located at one end of the channel means, and second signal detection means which is located at the other end of the channel means.

33. Apparatus according to claim 32 in which the signal means is a pump applying pressure which varies sinusoidally to the channel means.

34. Apparatus according to claim 32 or claim 33 in which the first and the second signal detection means are pressure gauges.

35. Apparatus according to any one of claims 32 to 34 in which the sensor is a pressure sensor.

36. Apparatus according to any one of claims 32 to 35 in which the signal processing means is a vector voltmeter.

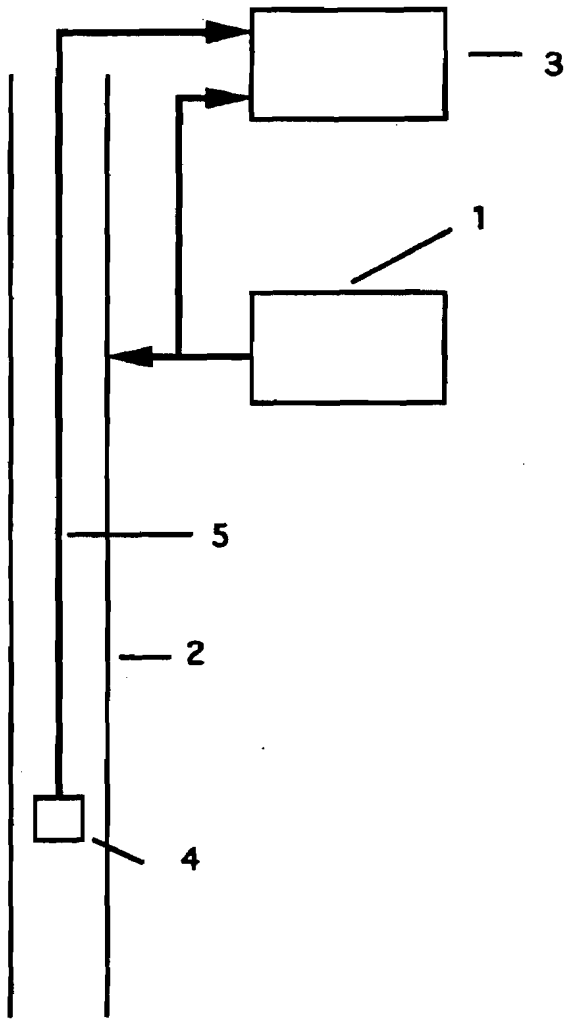

Figure 1

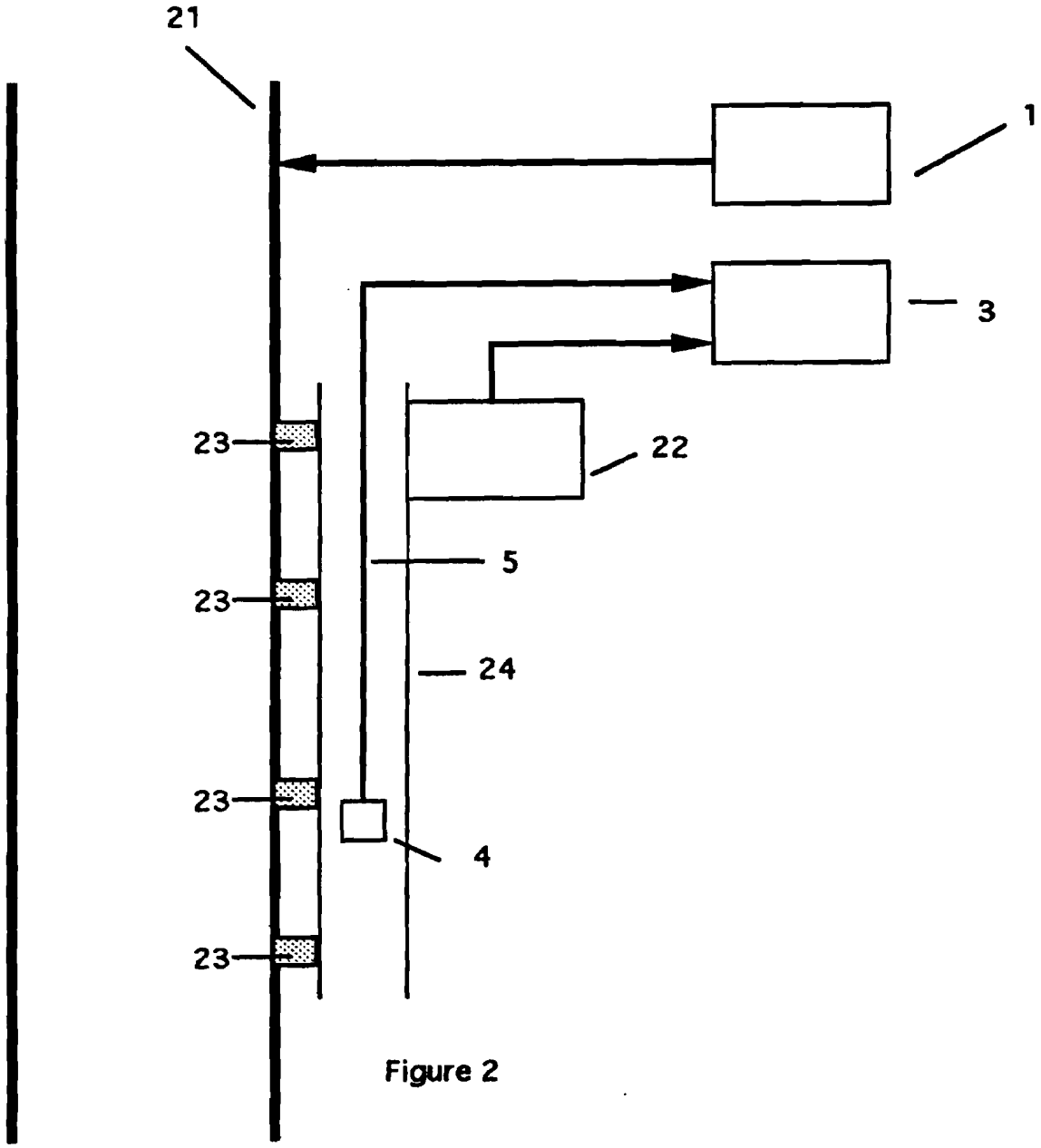

Figure 2

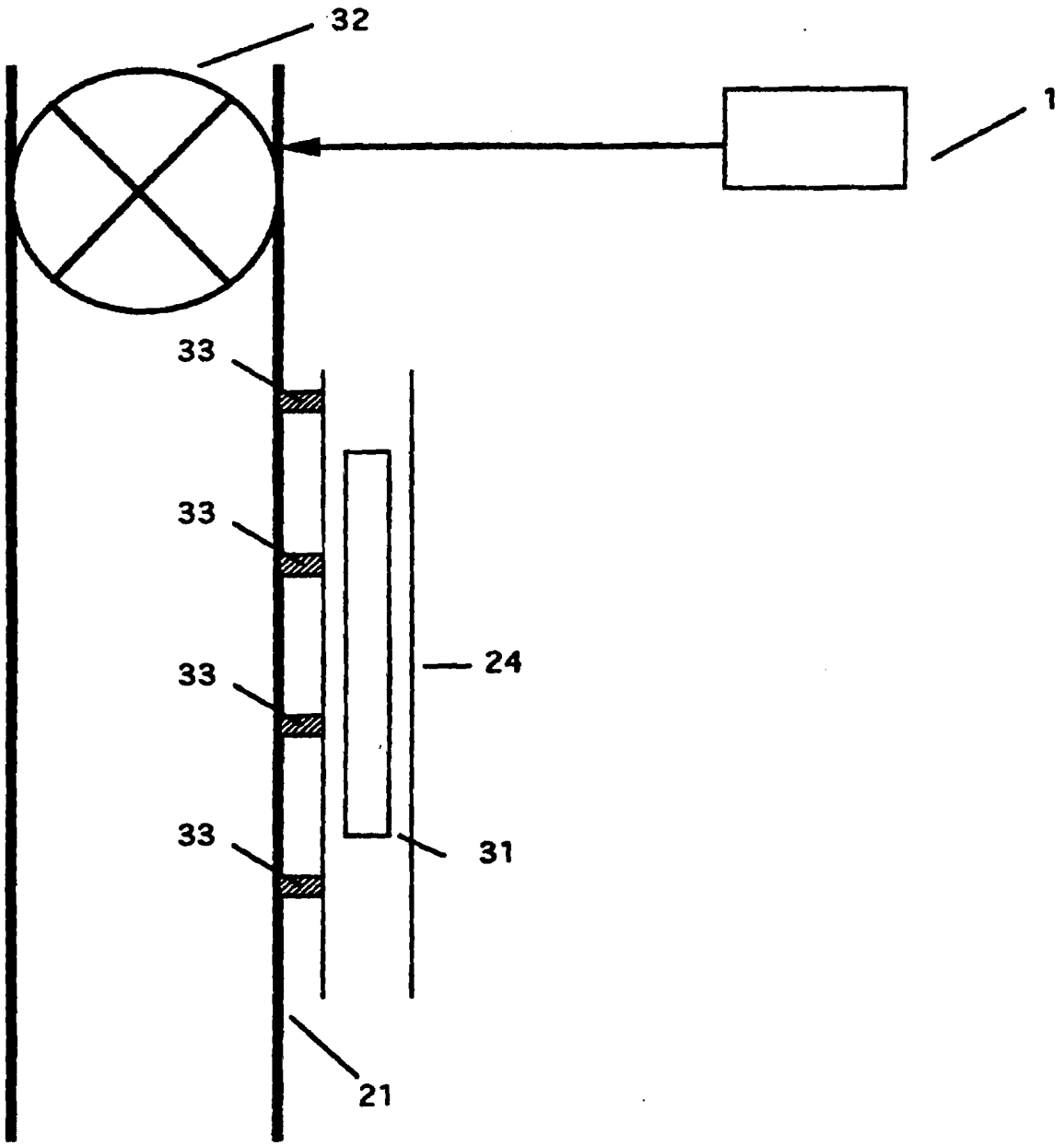

Figure 3

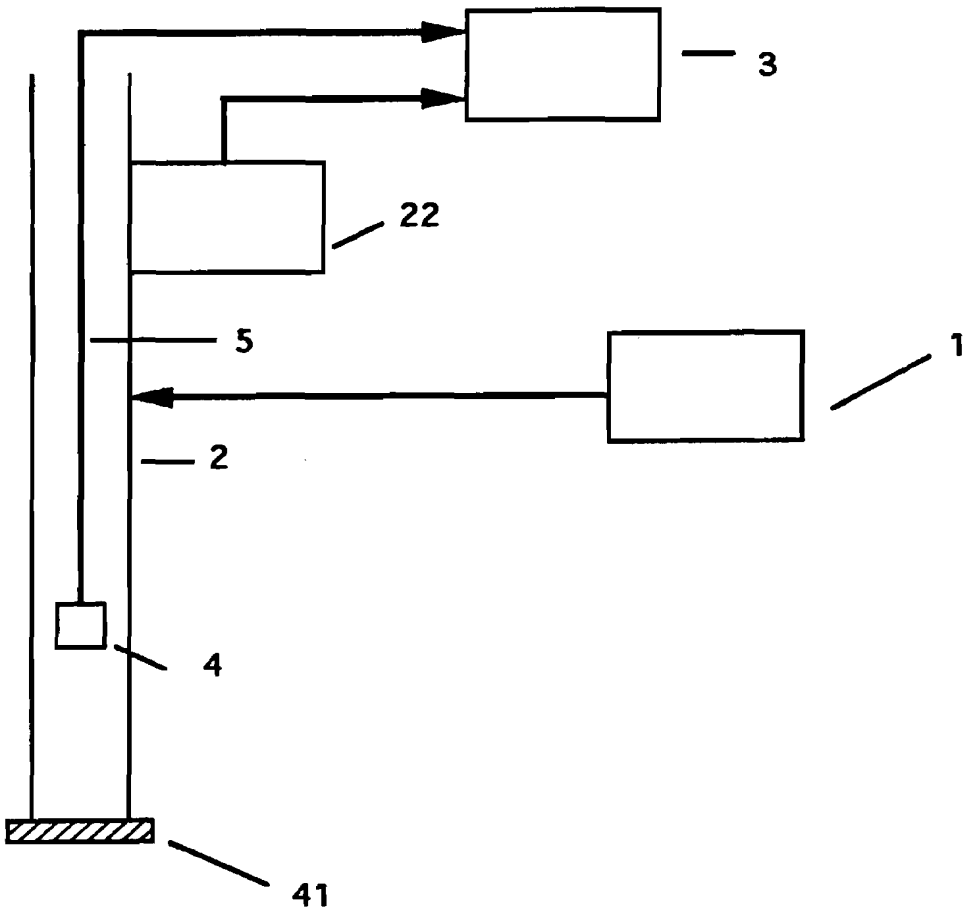

Figure 4

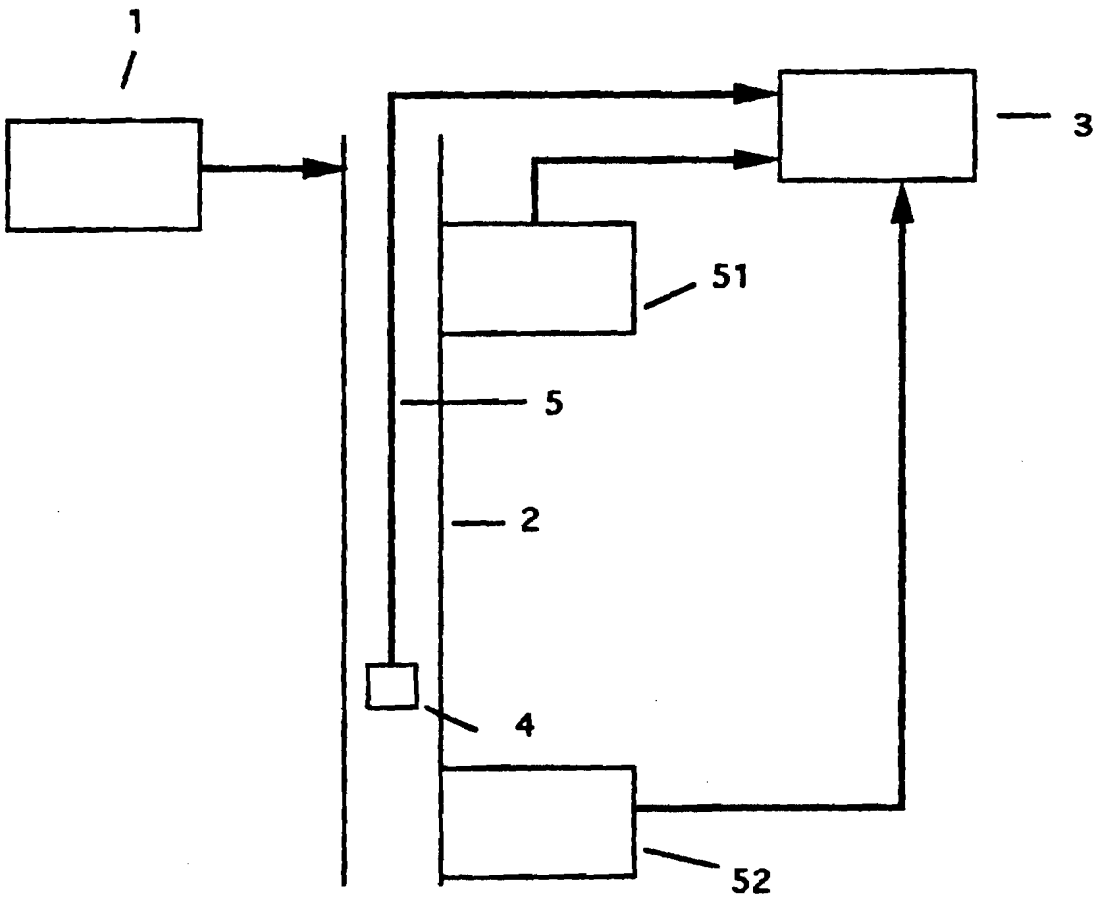

Figure 5

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 95/02234

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01V1/00 G01V1/40 E21B47/09

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01V E21B G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	see abstract	8
X	EP,A,0 084 468 (THOMSON CSF) 27 July 1983	1-7
A	see abstract; claim 1; figures 1,2	8
X	GB,A,2 208 004 (OWEN MICHAEL) 15 February 1989 see page 1 - page 2	1,2
A	EP,A,0 464 346 (STRABAG BAU AG) 8 January 1992 see abstract see column 2, line 44 - column 4, line 29	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
24 January 1996	-2.02.96

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International Application No
PCT/GB 95/02234

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y,P	GB,A,2 283 035 (CAMCO INT) 26 April 1995 see abstract; figures 1,4,12	8
A	SU,A,711 280 (TARAKANOV) 28 January 1980 see column 5, line 34 - column 6, line 34; figure	17
A	US,A,4 637 463 (MCCOY JAMES N) 20 January 1987 see abstract	18,19
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INTERNATIONAL SEARCH REPORT

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